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**Search for X-ray Emitting Young Stars
Outside of Massive Molecular Clouds**

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This project is intended to determine whether X-ray surveys of the sky can uncover previously unrecognized populations of pre-main sequence stars outside of large well-known star forming regions. X-ray observations of large regions such as the Taurus-Auriga complex, Orion molecular cloud, Ophiuchi and Chamaeleon clouds had revealed that low mass pre-main sequence emit X-rays $10^2 - 10^4$ above main sequence levels, and that X-ray surveys select a large population of 'weak' T Tauri stars that are not easily found in traditional optical and infrared surveys. The present project sought to find 'weak' T Tauri stars around smaller and more distant molecular clouds. X-ray surveys potentially could elucidate the star forming capabilities of small clouds, which are not well understood.

The investigation proceeded in a series of stages, analogous to searching for needles in a haystack. First, a large list of small molecular clouds and star forming regions was compiled from the literature. They included Bok globules, IRAS clouds, cometary nebulae, small high-latitude clouds, R and OB associations, and more. Second, the list was cross-correlated with Einstein Observatory X-ray archive, and a list of all Einstein sources within ~ 1 degree of each cloud was constructed. Third, these X-ray sources were cross-correlated with the new 20-million HST Guide Star Catalog. At this stage, there were 157 X-ray sources with $V=10-16$ magnitude stars in their error circles. Fourth, photographic finding charts of these targets were made, and the list was culled to select those most important for optical spectroscopic observation. Sources with well-known stellar counterparts, possible extragalactic identifications, far-southern declinations, and stars at fainter magnitudes were removed. Fifth, optical spectroscopy was performed on the priority targets to discriminate pre-main sequence from other stellar X-ray emitters. Sixth, the optical data were analyzed and the pre-main sequence emitters were identified.

Previous Status Reports describe the progress up to through Stage 4. It was considerably slower than expected due to a series of technical (e.g. inadequate software to read the incorrectly formatted HST GSC CD-ROM) and personnel (e.g. the graduate student on the project failed his Comprehensive Exams and left the Department) problems. However, during the last year these hurdles were overcome and the final stages of the project were completed. The optical spectroscopy observing proposal was accepted, though using the 1.9-meter telescope at Observatoire de Haute Provence (OHP) rather than the 3.5-meter telescope at Canada-France-Hawaii Telescope. This restricted the accessible magnitude and declination ranges somewhat. Nonetheless, seven excellent nights of CCD spectroscopic data at OHP were obtained on Muly 18-24 1987 by Dr. Francois Menard, who recently completed a dissertation on T Tauri star polarization. The data were sent to Penn State, where Dr. Alan, a young PhD expert in cool stellar spectra, reduced the data using the NOAO IRAF software. The data provide spectroscopic characterization of 26 stars associated with 17 IPC X-ray sources near small dark clouds. We obtained spectral types, $H\alpha$ emission strength with respect to spectroscopic standards (detectable even if it is below the continuum), and lithium 6707Å absorption.

While a final assessment of the results is still in progress, the following results are

emerging. There are quite few genuine 'weak' T Tauri stars in this sample, and hence few weak T Tauri stars outside of large molecular clouds accessible to imaging X-ray detectors such as the *Einstein* or *ROSAT* telescopes. Only two such stars were found by us: GSC 4279_0572, a 13m G0-G5 star with 0.15 ÅLi absorption and negligible H α associated with a weak IPC X-ray source in Seq. No. 6935 near a Bok globule and HII region Sharpless 2-161; and GSC 1605_0019, a 12m G1-G2 star with 0.30 ÅLi absorption and 3 ÅH α emission (above the expected absorption level) associated with a weak IPC X-ray source in Seq. No. 5905 near Bok Globule 13. We believe these two stars will be significant scientifically: they lie rather far from the centers of rather small molecular clouds which were not known to be actively forming stars. They thus may represent stars formed from an earlier (10^7 years?) epoch when the clouds were larger and more active. Nonetheless, since only two such stars were found, they do not by themselves represent a widespread phenomenon.

Several other interesting stellar counterparts to IPC X-ray sources were found, though they do not have incontrovertibly strong (> 0.07 Å) lithium absorption indicating stellar youth. These include GSC 6257_0328, an M4 star with 2 ÅH α absorption and very strong X-ray emission (probably a new nearby dMe flare star); GSC 1046_0421, 1067_0798, 2141_0820, 5131_0956, G stars with H α filled in or slightly in emission (likely new RS CVn-type binary systems); GSC 1608_0452, an apparent X-ray emitting double-lined spectroscopic binary; GSC 3504_1053 and 1605_0189, X-ray emitting A-F stars with H α filled in. Our survey, as expected, thus picked up non-T Tauri magnetically active stellar classes in the Milky Way.

A paper summarizing this work, and providing X-ray and optical data on the successful T Tauri discoveries and the other interesting stellar X-ray sources is in preparation. Authors will likely include the PI, Jerome Bouvier, James Leous, Francois Menard and Alan Welty. It will be submitted to the *Astronomical Journal* in mid-1992. The grant also supported the writing of an invited review paper, which is now published:

"Magnetic Activity in Pre-Main Sequence Stars", 1991, Eric D. Feigelson, Mark S. Giampapa, and Frederick J. Vrba, in *The Sun in Time* (C. P. Sonett et al., eds.), U. Az. Press, pp. 658-681.